CHEMISTRY OF WOOD

VI. The Results of Analysis of Heartwood and Sapwood of Some American Woods

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CHEMISTRY OF WOOD[1]

VI -- The Results of Analysis of Heartwood and Sapwood of Some American Woods

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This report contains the results obtained in the analysis of heartwood and sapwood of ten American woods. The work was undertaken to determine whether there is any uniform difference in chemical composition between sapwood and heartwood in either softwoods or hardwoods.

The methods of analysis used are the same as given in the preceding papers in this series.[2] All determinations were made in duplicate and the average is given in Table 1.

Discussion of Results

Ash content.--There is no general agreement in the relative ash content of sapwood and heartwood in the species examined.

Extractive content.--In general, the extracts of ether, cold water, hot water, and 1 percent sodium hydroxide are lower in the sapwood than in the heartwood of the softwoods. In the hardwoods the extractives are lower in the sapwood than in the heartwood of yellow birch, white oak, and yellow poplar, but the reverse is true of white ash and pignut hickory. Thus, from the standpoint of extractive content in sapwood and heartwood, the hardwoods analyzed are divided into two classes -- one class following the order of the softwood, the other following the reverse course.

Acetic acid.--The acetic acid obtained by hydrolysis is higher in the sapwood than in the heartwood of both classes of woods.

Methoxyl content.--The relative percentages of methoxyl in the sapwood and heartwood of the species analyzed cannot be arranged in any general order.

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[2]Jour. Indus. & Eng. Chem., Nov. 1922. 14, 1050.

Pentosan content.--There is a tendency toward higher yields of pentosans in the sapwood than in the heartwood of the species examined. The difference in yields, however, is slight.

Methyl pentosan content.--The methyl pentosan content in sapwood and heartwood of the same class is quite uniform.

Cellulose content.--For the relative cellulose content of sapwood and heartwood, the species analyzed, with the exception of yellow poplar, are grouped in a manner similar to that for extractives. All the softwoods examined have higher cellulose yields in the sapwood than in the heartwood. This tends to counterbalance the low extractives in the sapwood. One hardwood group, yellow birch and white oak with high extractives in the heartwood, has high cellulose content in the sapwood. The other group of hardwoods, white ash and pignut hickory with high extractives in the sapwood, has high cellulose content in the heartwood. The results obtained from the two yellow poplar samples, which are an exception to the foregoing scheme of grouping, can be explained by referring to the condition of the samples.

Both yellow poplar samples showed slight signs of decay in the sapwood. This condition would tend to increase extractives in the sapwood. The results show slightly higher extractives in the heartwood than in the sapwood, which indicates that on the basis of extractives yellow poplar is strictly a member of the first group of hardwoods. If it belongs to the first group, the cellulose content should be higher in the sapwood than in the heartwood, which is not the case. This can also be explained on the basis of the decayed condition which decreases the cellulose content in the sapwood, the reverse of what would be expected in sound yellow poplar.

Lignin content.--In softwoods, with the exception of white cedar, the lignin content is higher in the sapwood than in the heartwood. In the hardwoods all species except yellow poplar have a higher lignin content in the heartwood than in the sapwood.

A study of the ratio between methoxyl and lignin is shown in Table 2. A study of the results reveals the fact that the methoxyl-lignin ratio is approximately 50 percent higher in hardwoods than in softwoods. This ratio averages less than 13 percent in bald cypress. In Paper V of this series[2] it was shown that the methoxyl content of isolated redwood and live oak lignins was approximately 17.5 percent. Bald cypress lignin could not meet these specifications and, consequently, it must differ in chemical composition from redwood and live oak lignins.

Pentosan content of cellulose.--The pentosan content has a slight tendency to run higher in the sapwood cellulose than in the heartwood cellulose, similar to the results obtained in the original wood.

Methyl pentosan content of cellulose.--In general, the methyl pentosan content is slightly higher in the heartwood cellulose than in the sapwood cellulose. A similar relation was found in the heartwood and sapwood of the original samples.

Alpha-, beta-, and gamma-cellulose content of cellulose.--The percentages of the three kinds of cellulose in sapwood and heartwood cellulose cannot be grouped in any definite arrangement.

Conclusions

From a study of the data given in this report the following conclusions may be drawn:

1. In softwoods the water, ether, and alkali extracts are higher in the heartwood than in the sapwood, and as a result the cellulose and lignin are correspondingly lower in the heartwood (except lignin in white cedar).

2. On the basis of extractives hardwoods are divided into two groups: (a) those with high extractives in the heartwood, and (b) those with high extractives in the sapwood. The former have high cellulose content in the sapwood; the latter in the heartwood.

3. Acetic acid by hydrolysis is higher in the sapwood than in the heartwood of both softwoods and hardwoods.

TABLE I—ANALYSES OF SAPWOOD AND HEARTWOOD OF SOME AMERICAN WOODS
(Results in percentage of oven-dry (105° C.) samples)

SPECIES	Sample	Moisture	Solubility in: Ash	Cold Water	Hot Water	Ether	1% NaOH	Acetic Acid	Methoxyl	Pentosan	Methyl Pentosan	Cellulose	Lignin	In Cellulose: Pentosan	Methyl Pentosan	Alpha	Beta	Gamma
White ash:																		
No. 2 sapwood	179	5.34	0.61	5.81	6.41	1.17	21.77	3.23	4.70	19.85	2.40	50.38	26.95	18.83	1.60	74.67	13.67	11.66
No. 2 heartwood	180	5.45	0.30	2.24	3.40	0.43	19.59	2.31	5.36	19.90	2.25	53.56	27.39	16.75	1.34	64.68	24.58	10.84
No. 3 sapwood	181	4.91	0.57	5.25	7.02	0.88	21.93	3.70	5.66	20.16	2.63	49.72	27.39	19.67	1.60	55.11	28.29	16.50
No. 3 heartwood	182	7.42	0.32	2.12	4.46	0.46	18.97	2.66	5.20	19.87	2.46	53.40	28.38	17.34	1.47	42.45	33.22	24.33
Yellow poplar:																		
No. 1 sapwood	187	4.30	0.48	1.29	1.98	0.27	16.74	3.12	5.81	18.37	3.28	58.13	23.08	15.52	2.21	50.13	30.74	19.13
No. 1 heartwood	188	3.79	0.39	1.50	2.08	0.43	17.70	2.89	5.86	18.47	3.11	59.57	22.19	14.97	2.40	61.30	20.20	18.50
No. 2 sapwood	189	3.79	0.36	1.45	2.51	0.13	16.91	3.33	5.89	18.82	1.22	58.02	23.86	19.01	0.78	34.32	48.52	17.16
No. 2 heartwood	190	3.88	0.33	1.45	2.89	0.58	17.57	2.73	6.03	19.08	1.13	59.47	23.69	17.83	1.47	36.67	42.75	20.58
Pignut hickory:																		
No. 1 sapwood	191	3.54	0.40	4.91	6.45	0.29	19.11	3.58	5.56	18.18	1.11	56.08	21.87	16.90	1.30	51.55	21.92	26.53
No. 2 heartwood	192	3.90	0.45	2.07	2.95	0.36	15.10	3.08	5.79	18.64	1.02	58.81	22.85	16.20	1.39	59.44	23.74	16.82
Yellow birch:																		
No. 1 sapwood	207	4.92	0.26	1.05	1.98	0.48	16.77	2.34	5.66	21.36	1.66	58.91	24.69	20.72	1.13	52.15	32.90	14.45
No. 1 heartwood	208	4.76	0.40	4.16	5.69	0.81	20.51	1.78	5.46	20.37	1.39	56.88	24.62	21.87	1.12	61.17	23.23	15.60
No. 2 sapwood	213	4.28	0.18	1.74	2.10	0.88	19.78	3.75	5.47	22.30	1.82	56.57	27.76	22.19	1.71	52.40	26.82	20.78
No. 2 heartwood	214	4.36	0.23	2.76	3.96	0.99	21.14	2.83	5.27	23.21	1.07	54.93	28.13	21.81	1.04	53.56	25.00	21.44
White oak:																		
No. 1 sapwood	209	7.71	0.57	2.55	4.11	0.46	21.11	3.44	5.95	23.25	0.90	49.53	32.34	24.74	0.88	68.07	15.27	16.66
No. 1 heartwood	210	7.70	0.43	7.33	10.15	0.71	25.81	2.59	6.18	21.82	1.57	48.68	32.74	24.22	0.58	67.33	11.84	20.83
No. 2 sapwood	211	7.09	0.37	4.27	5.73	0.65	21.69	2.47	6.02	21.72	0.94	53.18	31.14	24.81	1.20	53.81	22.63	23.56
No. 2 heartwood	212	6.99	0.42	4.76	6.60	0.62	22.67	2.97	5.64	22.08	0.91	52.12	31.30	24.54	0.96	52.96	20.41	26.63
Bald cypress:																		
No. 1 sapwood	183	4.72	0.48	0.72	1.42	0.23	8.55	0.77	4.35	8.03	4.38	54.86	35.01	6.25	1.85	76.09	5.93	17.98
No. 1 heartwood	184	5.30	0.30	2.79	2.99	4.87	10.59	0.48	3.94	6.67	4.49	53.10	33.06	5.84	1.80	76.83	3.94	19.23
No. 2 sapwood	185	6.72	0.86	1.76	2.30	2.80	10.63	0.65	4.99	9.23	3.34	50.94	35.31	5.89	1.65	58.18	26.91	14.91
No. 2 heartwood	186	4.72	0.95	3.27	3.49	7.93	13.56	0.29	4.07	7.88	3.36	49.18	32.27	6.33	1.25	57.38	24.75	17.87
White pine:																		
No. 1 sapwood	193	3.90	0.23	3.55	5.15	5.46	17.16	1.68	4.16	9.31	2.14	54.25	26.51	6.81	2.09	54.56	17.47	27.97
No. 1 heartwood	194	2.92	0.42	5.97	7.68	3.62	19.15	1.43	4.60	8.56	1.00	50.23	26.14	7.12	2.02	57.29	22.42	19.29
Yellow cedar:																		
No. 1 sapwood	195	3.97	0.28	2.13	3.41	1.00	11.72	2.05	4.40	8.47	1.75	58.12	29.03	7.60	2.44	54.61	26.59	18.80
No. 1 heartwood	196	4.00	0.18	2.88	4.12	1.32	12.77	1.53	4.81	8.69	1.85	56.08	28.73	7.78	2.73	...	20.17	...
White cedar:																		
No. 2 sapwood	197	5.59	0.64	2.18	2.82	..	11.02	1.17	5.07	11.61	0.94	55.77	29.85	10.35	1.77	73.78	0.99	25.23
No. 2 heartwood	198	6.39	0.21	1.94	3.22	..	11.41	0.84	5.00	10.79	1.72	55.19	31.39	8.52	1.58	61.47	22.23	16.30
No. 3 sapwood	199	6.02	0.48	3.02	3.96	1.44	12.71	1.11	5.23	10.82	1.16	55.02	32.14	8.95	1.28	69.17	14.04	16.79
No. 3 heartwood	200	6.48	0.27	2.80	4.01	1.87	14.14	0.74	5.09	10.36	1.56	54.42	32.42	7.97	1.32	55.22	24.74	20.04
Incense cedar:																		
No. 1 sapwood	205	6.46	0.47	1.92	2.97	0.67	11.16	1.33	5.95	12.08	0.45	49.09	34.73	10.14	1.24	50.69	12.98	36.33
No. 1 heartwood	206	7.27	0.30	4.74	7.08	4.78	19.99	0.68	6.21	12.04	0.56	44.53	33.67	11.68	1.31	66.62	11.05	22.33

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Table 2.--Ratio of methoxyl to lignin on oven-dry (105° C.) weight of the wood.

Species	No.	Lignin		CH_3O		$\frac{CH_3O \times 100}{Lignin}$	
		Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood
White ash	2	26.95	27.39	4.70	5.36	17.4	19.5
	3	27.39	28.38	5.66	5.20	20.0	18.3
Yellow poplar	1	23.08	22.19	5.81	5.86	25.2	26.4
	2	23.86	23.69	5.89	6.03	24.7	25.4
Black hickory	1	21.87	22.85	5.56	5.79	25.4	25.3
Red alder	1	25.97	25.68	2.29	5.33	20.4	20.1
	2	26.64	25.94	5.26	5.26	19.8	20.3
Bald cypress	1	35.01	33.06	4.35	3.94	12.4	11.9
	2	35.31	32.27	4.99	4.07	14.0	12.6
Eastern white pine	1	26.52	26.14	4.16	4.60	15.7	17.6
Yellow cedar	1	29.03	28.73	4.40	4.81	15.1	16.7
Southern white cedar	2	29.85	31.39	5.07	5.00	17.1	15.9
	3	32.14	32.42	5.23	5.09	16.2	15.7
Incense cedar	1	34.73	33.67	5.95	6.21	17.1	18.4

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